

Chemical and isotopic investigation of cold and warm inflows in the Gotthard Tunnels

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Groundwaters detected during the crossing of mountains chains by deep tunnel provide valuable information about subsurface flow conditions and rock-water heat transfer. The warm water inflows in the Gotthard tunnels also represent important low-enthalpy geothermal resources, due to their remarkable flow rates. The maintenance and administration building situated at the portals of the Gotthard Highway Tunnel are, in fact heated by these groundwaters.

This study is aimed to elucidating the origin of these groundwaters and the processes governing their chemical evolution, within the geological-hydrogeological framework of the Gotthard area. To achieve these objectives, thirty-five water samples were collected and analysed chemically (major and some trace elements) and isotopically (δD and $\delta^{18}O$): 21 from the Gotthard Highway Tunnel (GHT) and 14 from the Gotthard Exploration Tunnel of the new Swiss railway project (NEAT) through the Alps.

For the GHT water the outflows temperatures range between 8°C to 32°C, and the total dissolved solids (TDS) between 50 to 2000 mg/kg and for the GET waters between 11°C to 25°C and 220 to 2500 mg/kg.

Geologically the GHT is located within the Aar and Gotthard basement massifs, represented mainly of late Variscan granites and Permocarboneous volcanoclastic sequences with tight synclines of Mesozoic cover composed by evaporates and by dolomitic marbles. The GET crosscut the Lower Pennine nappes of Lucomagno-Leventina made up by orthogneiss and paragneiss and by a Mesozoic cover represented by evaporates and dolomitic marbles grading upward to a calcschist sequence.

Sampled water belong to the following hydrogeochemical types (Fig. 1).

Type 1: Ca-SO₄ intermediate to high-salinity waters with TDS of 660 to 2500 mg/kg and outlet temperatures of 11°C to 25°C. This type include most

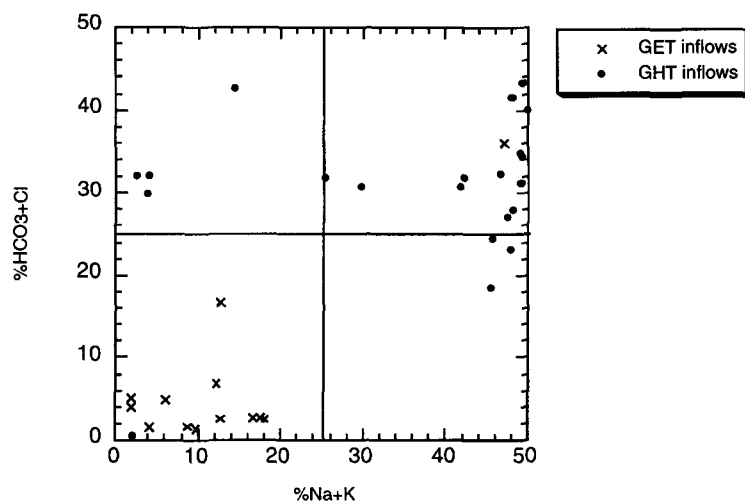


FIG. 1. Langlier-Ludwig square plot used for chemical classification of sampled waters.

of the waters collected in the GET and one sample from the GHT. The chemical feature of these waters are due to dissolution of anhydrite and/or gypsum contained in the carbonate metasedimentary cover of Mesozoic age.

Type 2: Ca-SO₄-HCO₃ to Ca-HCO₃-SO₄ low salinity waters, which include one sample of the GET and 4 samples from the GHT. (TDS of 50 to 225 mg/kg and outlet temperatures of 8.8 to 16°C). The chemistry of these waters may be explained (a) by relative quick circulation through the evaporate rocks of the Mesozoic cover, and/or (b) by mixing of high-salinity Type 1 waters with Ca-HCO₃ shallow water percolating the gneissic rocks.

Type 3: Na-SO₄-HCO₃ to Na-HCO₃-SO₄ type with low to intermediate salinity (TDS of 100 to 250 mg/kg and outflows temperature of 16°C to 32°C). They originate in circuits entirely hosted in granitic/gneissic rocks. The varying SO₄/HCO₃ ratio of this type of waters reflects the relative importance of (a) dissolution of sulphides followed by dissolution of silicate driven by sulphuric acid vs (b) dissolution of silicates governed by carbonic acid.

Type 4: Na-Ca-HCO₃ low salinity type which includes two samples from the GHT (TDS of ~ 65 mg/kg and outlet temperature of 21 and 23°C). Low mineralization suggest limited water-rock interaction with granitic/gneissic rocks.

Stable isotope investigation point-out that all samples have a meteoric origin and that no rock-water exchange at high temperature occurred. Variations in isotope values is caused by differences

in elevations of the zones of rain infiltration.

The comparison of the temperature of the GHT waters with those of the neighbouring rocks suggest that water-rock thermal equilibrium is frequently achieved. Chemical geothermometers provide discordant temperatures suggesting that these waters are not in chemical equilibrium with rocks. These inflows are there interpretable as descending meteoric waters instead of upflowing waters coming from deeper levels.

In the geological-hydrogeological framework it seems likely that the pathway of downwards percolating waters and the extend of water-rock interaction are largely controlled by permeability conditions. Variation in the chemical characteristics are mainly due to both changes lithology and mixing between different water types.

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